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An Implementation of the Multiple Integrated
Laser Engagement System (MILES) on an
Unmanned Ground Vehicle (UGV)

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13. ABSTRACT (Maximum 200 words) This report describes the use of the Army's multiple integrated laser engagement system (MILES), as installed on an unmanned ground vehicle (UGV), for a field training exercise with armored scouts of III Corps First Cavalry Division. The electronic circuitry interfacing the MILES to the UGV is described in detail. The report includes tutorial material about MILES and a brief description of Project Mustang.					
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AN IMPLEMENTATION OF THE MULTIPLE INTEGRATED LASER ENGAGEMENT SYSTEM (MILES) ON AN UNMANNED GROUND VEHICLE (UGV)

1. INTRODUCTION

As the U.S. Army moves toward using unmanned ground vehicles (UGVs) in combat roles, doctrine must be developed describing how these resources will be used, and the user must be familiarized with the capabilities and benefits of this new battlefield technology. The first exposure of troops to UGVs will be in field training exercises. The multiple integrated laser engagement system (MILES) is the mechanism used by the U.S. Army to simulate the effects of weapons fire in such exercises. This report describes how MILES equipment from the Army inventory was adapted to a UGV in a training exercise with the armored scouts of III Corps First Cavalry Division.

2. PROJECT MUSTANG

Project Mustang, begun in 1994 at the U.S. Army Research Laboratory (ARL), put a UGV into an Army field training exercise for the first time. The UGV was tailored to the role of the Armored Cavalry Scouts in an effort to evaluate how this technology could best be used by soldiers who regularly find themselves in harm's way. LTC Richard Lynch, CO 1-8 Cavalry Battalion, 1st Cavalry Division, provided sponsorship and guidance in how the UGV was to be used. Scouts under his command provided detailed user input, and ARL scientists and engineers tailored the capabilities of the robotics test bed (RTB)¹ to the user requirements. The scouts also served as operators for the UGV, nicknamed "Dark Horse," in exercises at Fort Hood, Texas, in 1994 and 1995.

As used in these exercises, the UGV was driven by a scout to a strategic overwatch position. On the way to this position, the scout caused the UGV to record a fall-back path, which the UGV could retrace ("retrotraverse") on command. At the overwatch position, the scout, using a suite of self-prompting push buttons providing communication to the UGV computers, set up areas of interest for the infrared (IR)-based automatic target acquisition (ATA)

¹RTBs are ARL resources, developed as technology test beds and demonstrators of the capabilities of telerobotics for military operations. Their development is described in Haas, David, and Haug (1995).

system and transferred control to the base station. The scout was then picked up by another scout vehicle and returned to other duties.²

The now-unmanned UGV passively monitored the areas of interest, watching for anything moving that might indicate a target. When a possible target was sighted, the UGV radioed a snapshot of the target to the base station, co-located with the battalion tactical operations center (TOC). The operator, having verified that the snapshot truly corresponded to a target, had several choices of action. His primary role was to report the target to the battalion Intelligence Officer, but he could also fire a laser rangefinder at the target to establish range, capture a visible light telephoto image of the target, or shoot the target with the UGV's simulated 25-mm cannon. At the time of the field exercises, the system could not develop map coordinates of the targets, but plans are in place to implement this capability. This enables the UGV to simply report the map location of the target to some weapon system responsible for destroying the target. This capability (termed "target handoff") allows the UGV to specialize in acquiring and locating targets, while some other systems can specialize in engaging and destroying targets.

3. MILES WEAPON SIMULATOR SYSTEM

In such training exercises, the U.S. Army uses a laser-based weapon simulator system called the multiple integrated laser engagement system (MILES). It "uses eye-safe laser bullets" (to quote sales literature) to allow soldiers to practice combat on each other without actually causing casualties. A MILES package for a typical weapon system (e.g., a Bradley fighting vehicle [BFV]) consists of a controller box, an IR laser transmitter that fires instead of the Bradley main gun, a set of IR hit detectors that detect when the Bradley has been hit by another MILES transmitter, and a flashing light that goes on when the sensors detect a hit. The simulator for each type of weapon is tailored to represent certain essential characteristics of the real weapon. For example, the Bradley main gun simulator transmission fades at about the same range that the Bradley main gun loses effectiveness. Furthermore, a code representing the type of weapon being simulated is modulated on the transmission.

When the hit detectors sense incident laser radiation from a MILES transmitter, the controller box decodes the type of weapon and performs a Monte Carlo determination, based on probability of kill for the specific weapon on the specific target, whether the target has

²In the context of the training exercise, the two scouts proceeded to a location nearby, in sight of the UGV. They then served as UGV safety monitors for the duration of the mission. In actual combat, these scouts would be freed for other duty.

experienced a "kill" or merely a "hit." If the power of the incident radiation is below a threshold, a "near miss" event is registered. The occurrence of such an event activates an external flashing light and an aural alarm, intended to alert the crew of the target of its combat status on the battlefield. The number of flashes and "beeps" depends on the type of event; when the crew sees continuous flashes and beeps, they know that they have been "killed," and that their part in the exercise is over.

A UGV, however, has to perform its most significant role (in this case, target acquisition) unmanned, with no crew present to see the lights or hear the beeps. It would not be fair for the UGV to continue its mission, zombie-like, after having experienced a kill. So for Project Mustang, it was determined that the computers controlling the UGV must somehow detect the alarms from the MILES controller box and stop the UGV systems.

4. UGV-MILES INTERFACE

The UGV used in Project Mustang was already equipped with a BFV MILES weapon simulator, used in demonstrations of automatic target acquisition and engagement. The BFV kit was selected because the simplicity of its trigger interface made it easy for the computer to fire the laser transmitter. For Project Mustang, the entire interface to the MILES controller, including both firing and alarm detection, was redesigned.

Early in the project, it was not clear whether the rules of engagement would allow the use of the BFV MILES kit for hit detection, since the BFV kit would make the UGV unrealistically difficult to kill. It was proposed that a mobile independent target system (MITS) kit, the standard hit detector for unarmored targets such as trucks and high mobility, multipurpose wheeled vehicles (HMMWVs), would provide hit detection with probability of kill factors more appropriate to the UGV. The MITS would be installed alongside the BFV MILES kit, with the BFV kit providing the weapon simulator and the MITS the hit detection. However, the use of the BFV unit for both functions was cleaner from an interfacing perspective. To cover both cases and possible future exercises using the new simulated area weapons effects (SAWE) MILES being introduced at the National Training Center, the interface was designed to handle a range of hit detection inputs.

The interface, then, has two components: 1) weapon firing signal generation; and 2) alarm detection. A block diagram of the interface is shown in Figure 1.

J2 PinOut	
Pin	Signal
J	24 v.
K	Return
C	TOW Latch
F	MP2
D	25mm ATR
E	WEAPON
G	Coax

P7/8 Pinout	
Pin	Signal
7	Audio
8	Audio Retn

P6 Pinout	
Pin	Signal
1,3	24 v Retn
2,4	24v

P4 Pinout	
Pin	Signal
B	12 v Retn
A	12v

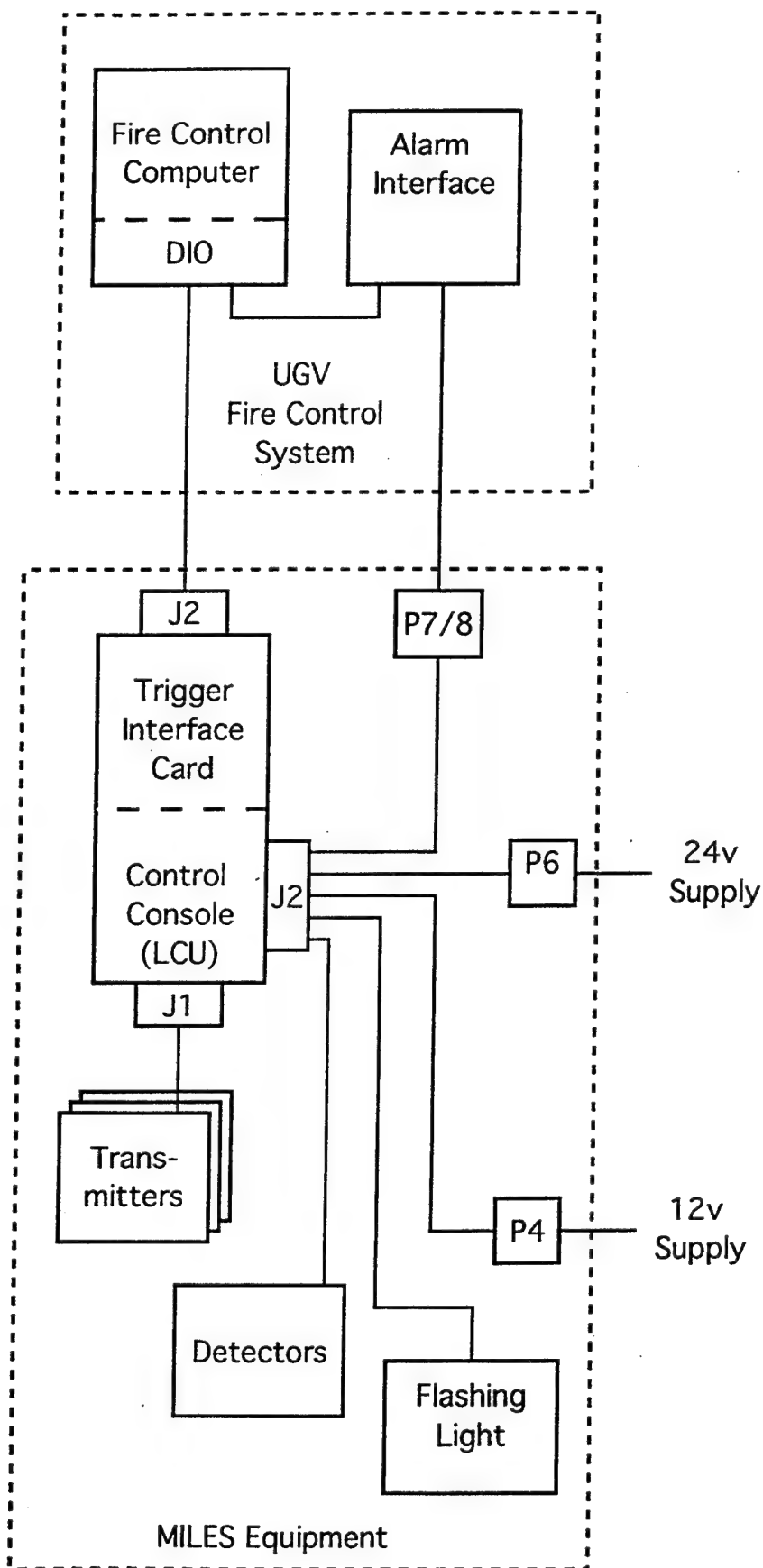


Figure 1. MILES Interface Block Diagram.

5. WEAPON FIRING SIGNAL GENERATION

When a BFV MILES kit is installed in a BFV, the trigger circuitry is connected to the MILES controller by plugging a cable from the MILES kit into a socket beneath the BFV floor plate. In Project Mustang, the firing signals were to be generated by a control computer with commercial input/output (I/O) cards and interfaced to the MILES controller through the same connector. Fortunately, the legwork of finding MILES documentation and reverse engineering the signals had already been done in the RTB project. It is documented here for the first time.

The trigger interface card in the MILES controller box isolates the MILES circuitry from the BFV circuitry by means of optoisolator chips, as shown in the schematic diagram of Figure 2. In the schematic, the signals \overline{TMISL} , \overline{TMGUN} , and \overline{TCOAX} , cause the transmitters simulating the tube-launched, optically tracked, wire-guided missile (TOW)³, 25-mm cannon, and coax machine gun, respectively, to fire. Thus, to fire the main gun, the trigger interface need only apply 12 volts to the input signals "25mm ATR" and "WEAPON." The identification code is modulated on the transmission by circuitry (not shown) downstream from the trigger interface.

A modified digital I/O (DIO) card in the Project Mustang control computer provides the "WEAPON" signal, used as a safety, and the "25mm ATR" signal used to trigger the transmitter. The "WEAPON" signal is maintained in a "safe" state by a pull-down resistor until the "arm" subroutine is executed. The "arm" subroutine applies +12 volts from the DIO port to the "WEAPON" pin. The "fireWeapon" subroutine checks a software flag to confirm that the cannon has been armed and then applies +12 volts from the DIO port to the "25mm ATR" pin for a software-configurable period of time (typically about 1 second). This causes the cannon transmitter to send its encoded "bullets" at a rate consistent with the firing rate of the BFV, hopefully causing simulated hits or kills to a hapless player on the opposing team.

6. ALARM DETECTION

When a BFV equipped with a MILES kit is hit by "bullet" signals from a MILES-simulated weapon, the visible alarm flashes and a tone is sounded on the BFV intercom system. When the BFV kit is installed on a UGV, it is easier to intercept the signal to the intercom system than the signal to the flashing light, as the connection to the intercom is discrete wires, while the connection to the flashing light is commingled with other signals in a multi-pin military connector.

³In Project Mustang, the coax machine gun and TOW simulators are not implemented.

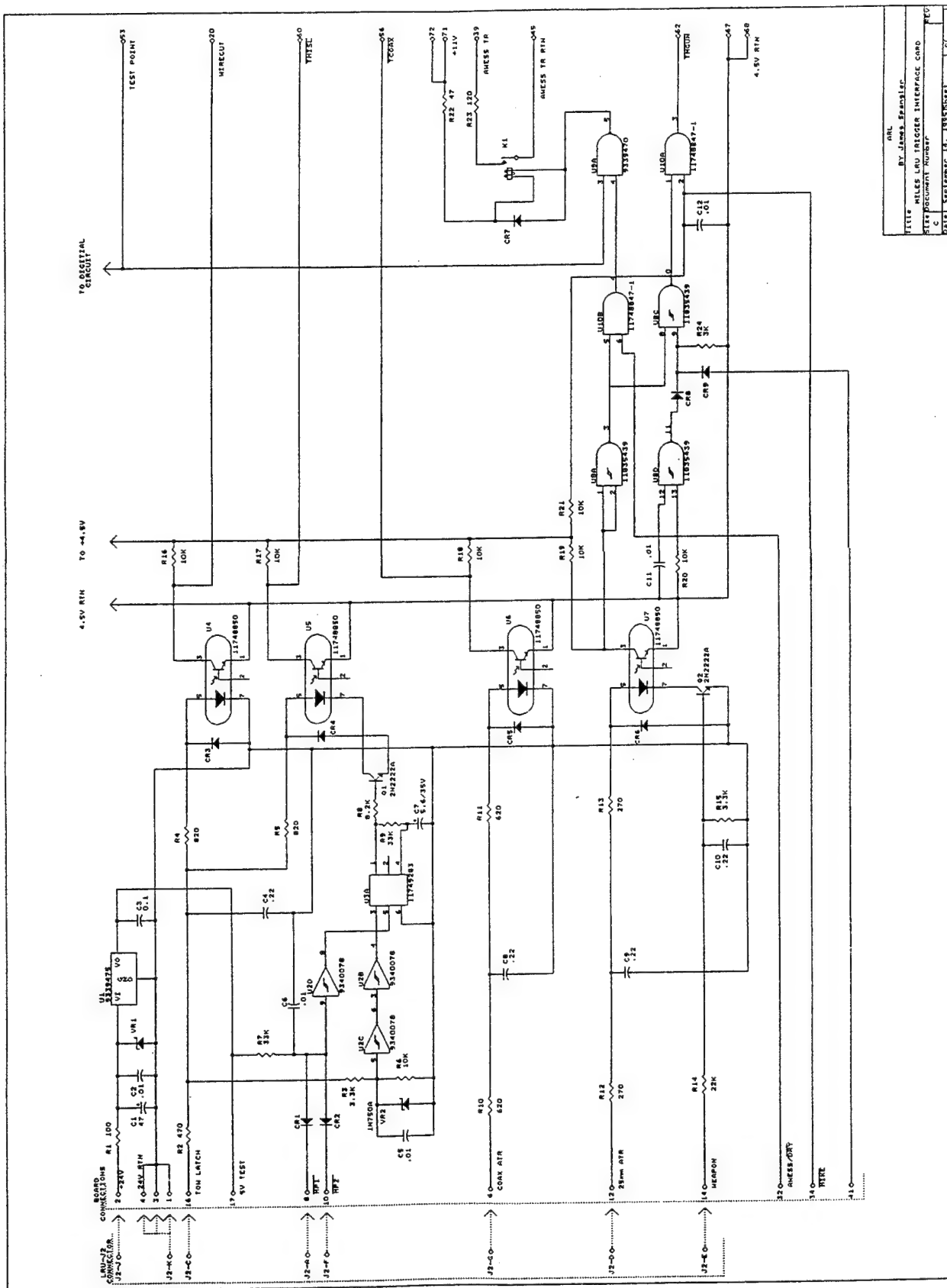


Figure 2. MILES Control Console Trigger Interface Card.

The intercom tone is generated by the MILES control console as 1-second bursts of a 2.5-kHz DC square wave, with the number of 1-second tones varying, depending on whether the triggering event is a near miss (one or two tones), a hit (four to six tones) or a kill (tones continue until reset with a key).

It was decided that the easiest approach was to process the alarm signal in hardware to convert pulse trains to tone detections, count the detections, and map detection count to one of four "hit states." Software would then monitor the hit state periodically, interpret, and take whatever action was indicated.

On the interface board, the pulse train is amplified, smoothed, and given a more sinusoidal form by a "pulse-stretching" capacitance before being fed to an LM567-based phase-lock-loop (PLL) circuit. Adjustment is provided to account for variability in the exact frequency of the tone. The output of the PLL is fed to a 4017-decade counter chip, which converts the "tone detect" signal to 10 one-bit-wide "tone count" signals. Four DIP switches select the value of "tone count," which corresponds to crossing from one hit state to the next, as shown in Table 1.

Table 1
Hit State Transition

Hit State	Transition Count
All clear	<reset>
Under fire	1
Hit	3
Killed	7

The four one-bit-wide hit state signals, optionally latched, switch reed relays that convey the output state to the DIO board for interpretation. A number of light-emitting diode (LED) indicators indicate internal states.

A logical block diagram of the signal processing is shown in Figure 3. The schematic that implements the signal processing is shown in Figure 4.

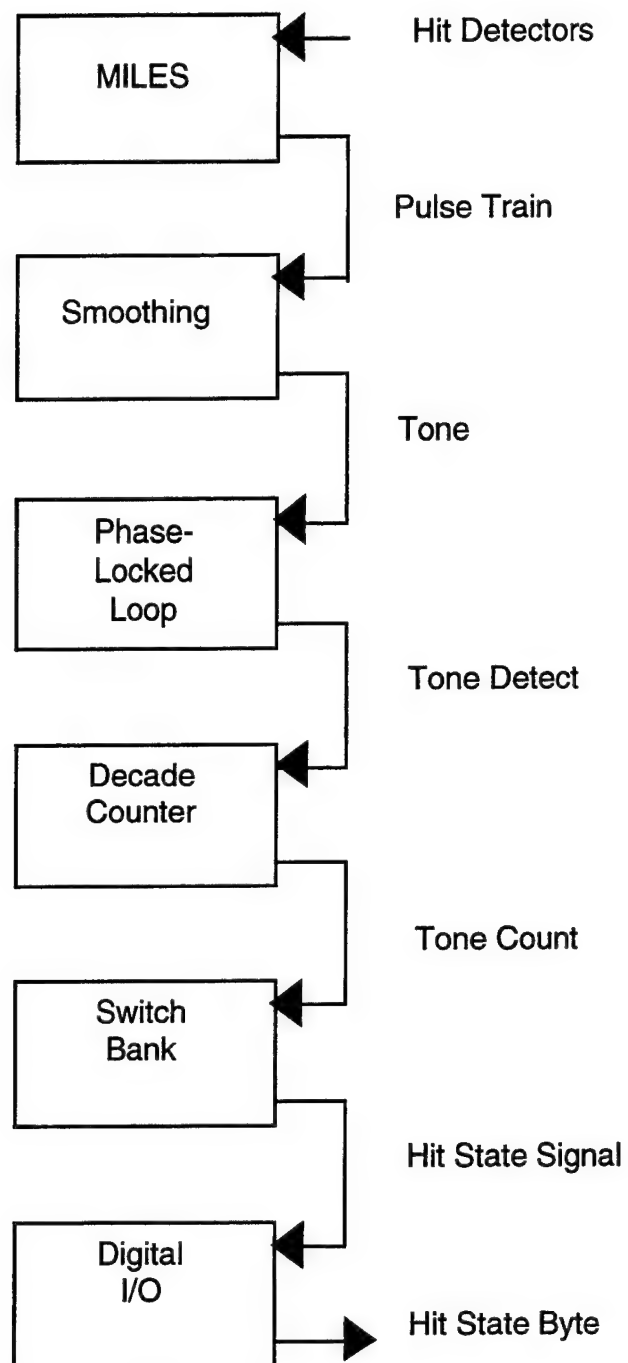


Figure 3. Block Diagram of Alarm Processing.

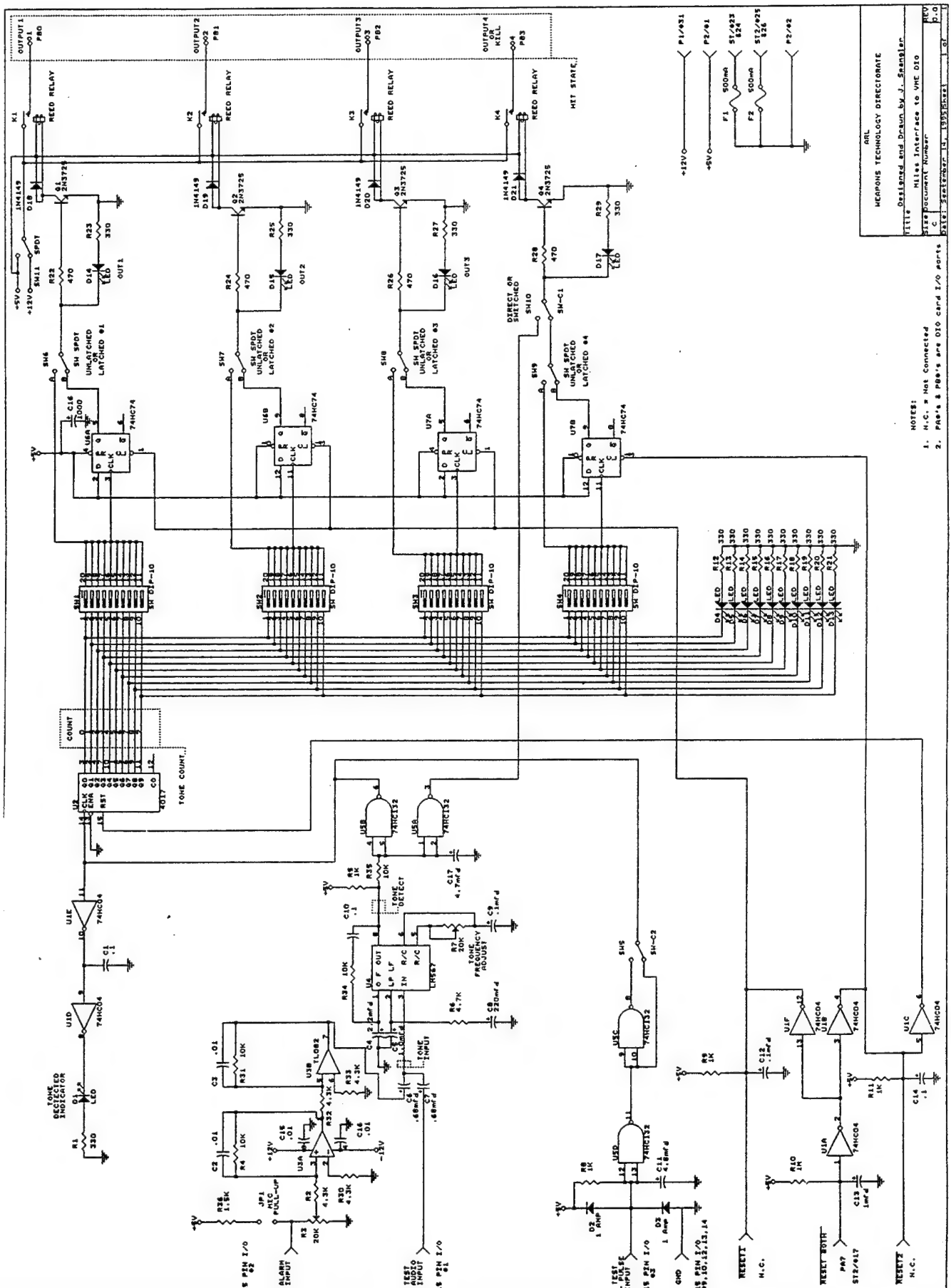


Figure 4. Schematic of Alarm Processing.

While the MILES control unit can detect the difference between “near miss” and “hit,” from the standpoint of the UGV there is no difference in the reaction required (presumably, to seek cover or evacuate the area). So the UGV state table has only three states: “all clear,” “under fire,” and “killed,” with state table as shown in Figure 5.

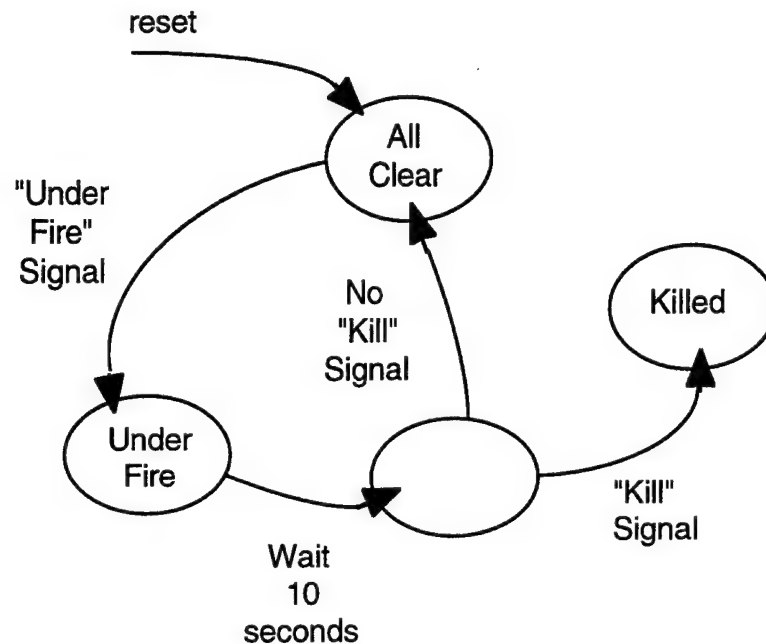


Figure 5. State Diagram.

However, it is possible that the UGV can experience several “near misses” which would cumulatively result in a “tone count” of more than the “kill” count, which would be interpreted (incorrectly) by the hardware as a “killed” state. The software must determine the difference.

Under control of a watchdog timer, the VxWorks®-based software monitors the DIO port several times a second. In its normal state (“all clear”), it checks the “under fire” signal only. If the “under fire” signal becomes active, the software alerts the remote operator of the UGV that it is under fire and changes its software state to “under fire.” In this mode, it monitors the “kill” signal only. If the “kill” signal becomes active, it alerts its remote operator that it has been killed and terminates. Otherwise, it checks to see how long (how many iterations of the watchdog timer) it has been “under fire,” because the continuous stream of 1-second tones of a true MILES “kill” will trigger the “kill” bit in 7 seconds. If it has been “under fire” for more than 10 seconds (that is, the 7 seconds it takes for the counter to reach the kill count of 7, plus an arbitrary 3-second margin), it concludes that it has not been killed and re-enters the “all clear” state. (The

logic can be paraphrased as "It's time for me to be dead, but I'm not dead, so I must be okay".) Transition to the "all clear" state causes the counter and latch hardware to be reset, the software state to be set back to "all clear," and the remote operator to be alerted that all is once again clear at the UGV.

This logic is not foolproof in a situation when the UGV experiences a number of "hit" or "near miss" events proximate in time. It may decide that it has been killed when it has only experienced seven misses in 10 seconds, however unlikely that may be. It may also decide it is "all clear" when it has experienced a miss and several seconds later, a kill, but the cumulative tone count does not reach 7 within the 10-second window. However, its reaction to a "kill" event is at worst 20 seconds, and other misinterpretations of the state of the MILES control unit are either unlikely or temporary.

The alternate hit detector, the MITS, uses a small piezoelectric buzzer integral to the MITS control box as its audio alarm. The hit state is encoded in a manner similar to that of the BFV MILES, that is, the number of beeps indicates the hit state. Because our MITS equipment was borrowed, it was decided that the audio alarm should be acquired in audio form and converted to an appropriate electronic signal, rather than intercepted from within the MITS box while still in electronic form. This is also a mode likely to work with the new generation SAWE MILES apparatus.

To detect such acoustic alarms, a small capacitive microphone is mechanically affixed to the orifice of the buzzer, using adhesive and foam to exclude extraneous noise. A voltage source for the microphone is connected to the microphone lead by means of a jumper JP1 on the interface board.

7. CONCLUSION

During the field exercises at Fort Hood, the UGV was never fired upon by anything larger than small arms, but the interface to the hit detector interface was thoroughly verified with the controller gun used by exercise referees. The BFV weapon simulation was used together with the target acquisition algorithms to demonstrate the ability to address moving targets. The system was not used to engage targets during the exercises because of the nature of scout missions and the ground rules for interacting with the training exercise. The interface to the MILES is an essential detail if UGVs are to be exercised with soldiers in field exercises. The MILES interface will find use in a variety of scenarios for military UGVs (whether a weapon is considered or not)

but is instrumental in demonstrating weapon and targeting applications without the additional safety and technical burden of controlling a lethal weapon.

8. REFERENCES

Haas, G., David, P., and Haug, B.T., Target Acquisition and Engagement from an Unmanned Ground Vehicle: The Robotics TestBeds of DEMO 1, October 1995.

System Maintenance Manual (Including Repair Parts and Special Tools List) for Simulator System, Firing, Laser: M83 (1265-01-158-4560) for M2/M3 Fighting Vehicles, SMM 1265-375-24&P, September 1989.

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APPENDIX A
PROJECT MUSTANG PHOTO

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Figure A-1. Project Mustang Photo.

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